FILTER FOR RETAINING A SUBSTANCE ORIGINATING FROM A RADIATION SOURCE AND METHOD FOR THE MANUFACTURE OF THE SAME

The invention relates to a method of manufacturing a filter for retaining a substance originating from a radiation source as defined in the opening part of claim 1, and to a device as defined in the opening part of claim 12. The invention also relates to the use of a device according to the invention in EUV lithography.

EUV lithography is to be used in the near future for mass manufacture of integrated circuits. Radiation sources are necessary for this which provide in particular a high output power for the irradiation of wafers. Two radiation source designs are particularly promising in this respect, given the present state of knowledge.

In the so-termed laser pulse plasma method, a substance is introduced in the form of a target into the focus of a pulsed laser beam. The target is evaporated owing to absorption of the laser beam. In addition, the substance is ionized so strongly at least in part that it emits rays in a wavelength range from 10 nm to 14 nm.

In the second type of radiation source, a substance in the form of a working gas is excited by means of electric discharge so as to form a plasma which emits EUV rays.

A particularly serious problem in these two radiation sources is formed by contamination of optical components inside an EUV lithography device owing to the deposition of substances originating from the radiation source.

JP 2000 349 009A discloses a filter which is permeable in particular to EUV rays and which retains the substance xenon. This filter is naturally unsuitable in particular for high-power radiation sources because particularly substances having a high conversion efficacy – i.e. the ratio of output power of the EUV rays to the energy coupled in – will block a collector mirror used for this purpose within a very short period. Thus, for example, a monoatomic layer of tin atoms on the collector mirror already reduces the reflection coefficient thereof by approximately 10%. The filter is in addition exposed to a very high radiant intensity, because the output power of the EUV rays passes through a comparatively small filter surface.

Furthermore, silicon nitride membranes in the form of windows have been used in electron microscopy. These windows are standardized to a maximum size of 25 mm^2

because of their low mechanical stability. This comparatively small window surface area inhibits an industrial application in EUV lithography.

Thin metal foils have been used for reducing radiation outside the wavelength range of EUV radiation and for protecting the optical systems of an EUV lithography device at least partly against contamination by the radiation source. A strip-shaped frame of nickel metal was adhered thereto to improve the handling properties. The adhesive used was epoxide.

It was found that such epoxide connections are unsuitable for use in high-power radiation sources under the prevailing thermal conditions.

The present invention accordingly has for its object to provide a method and a device having the features referred to in the opening paragraph, which comprise technically simple means, can be used in particular for high-power radiation sources, and ensure a continuous transmission of the EUV radiation during operation.

According to the invention, this object is achieved by means of a method of manufacturing a filter for retaining a substance originating from a radiation source, which filter comprises a thin layer that is transparent to extreme ultraviolet and/or soft X-ray radiation, and which filter is resistant to high temperatures.

This provides the advantage that the filter can be positioned comparatively close to the radiation source. A high thermal loading capacity of the filter is necessary because of the absorption effects and the thermal transmission by the substance. A power transmitted thereby onto the filter lies in a range of approximately 1000 W. Assuming a radius of approximately 5 cm for the filter, it follows from the Stefan-Boltzmann law that the filter will reach a temperature of approximately 1225 K.

It is of particular advantage for the method if first the thin layer and subsequently a support structure for the thin layer are manufactured, or in reverse order, wherein the filter is constructed such that the thin layer is connected to the support structure in a manner resistant to high temperatures.

As a result of this, the filter can be constructed with a large surface area. The radius of the filter thus increased reduces the thermal load on the filter, given a constant power of the radiation source. Filter life is considerably increased because its material is less strongly loaded.

Preferably, the method is designed such that at least the thin layer is manufactured in a chemical and/or physical deposition process.

Obviously, all methods known to those skilled in the art may be used for manufacturing the thin layer. If manufacturing processes based on conventional thin-film techniques are used, however, very homogeneous layers can be generated on a suitable substrate, which layers, for example, have good optical properties, such as transmission of EUV radiation, over a large surface area within narrow limits. Conventional methods comprise, for example, CVD and PVD processes.

A particularly advantageous embodiment of the method provides that at least the thin layer comprises preponderantly zirconium, niobium, molybdenum, silicon, zirconium carbide (ZrC), zirconium dioxide, silicon carbide (SiC), silicon nitride (Si_3N_4), boron nitride (BN), or a combination thereof.

These materials are remarkable for their good optical properties such as, for example, a high transparency to EUV radiation and a high structural integrity of a thin layer manufactured therefrom over a wide temperature interval.

The method of manufacturing a filter may be further developed such that the thin layer and the support structure are integrally manufactured.

This has the result that thermally induced stresses between the thin layer and the support structure are at least largely avoided in particular during heating and cooling-down of the filter according to the invention.

To ensure on the one hand a high transmission coefficient for the EUV radiation and on the other hand a high mechanical stability of the thin layer, the method is advantageously further developed such that a layer thickness of approximately 100 nm is achieved for the thin layer. Layer thicknesses in the range of 100 nm can be manufactured inexpensively and in a mass manufacturing process by means of the methods mentioned as examples above.

A particularly advantageous embodiment of the method provides that also the support structure comprises preponderantly zirconium, niobium, molybdenum, silicon, zirconium carbide (ZrC), zirconium dioxide, silicon carbide (SiC), silicon nitride (Si_3N_4), boron nitride (BN), or a combination thereof.

It is possible in particular with the use of the same materials, for example, to avoid thermal stresses between the thin layer and the support structure.

The method can be improved such that a thickness of approximately 1 μm up to 1 mm is set for the support structure.

The mechanical properties of this filter according to the invention can be adapted to the relevant application through variation of the thickness of the support structure.

It is obviously also possible to use materials for the filter which simplify handling, transport, and storage. The methods are for this purpose designed such that a material having a melting point of at least 1300 °C is chosen for the thin layer and the support structure.

The material is capable of improving both the optical and the mechanical properties of the inventive filter by means of dopants. A complete, substantially extremely thin coating of the material is capable of strongly simplifying in particular the handling of the filter outside a vacuum chamber in which the radiation source is accommodated. This coating serves for passivation, similar to an oxide layer on an aluminum component. The material, however, may equally well form part of the support structure which supplies additional mechanical stability, for example in the form of an outer frame.

The methods are advantageously further developed such that the support structure is constructed as strips, for example forming a grid structure or honeycomb-type woven structure.

It is achieved with this construction that a load change occurring in the EUV lithography device is diverted via the support structure, for example in the case of a change in pressure conditions.

Such structures can be prepared, for example, by means of a suitable deposition on a previously manufactured thin film, which acts as the thin layer. It is provided in a further embodiment of the invention, however, that the woven structure is generated by means of erosion, laser processing, or photochemical etching. To achieve this, for example, a second layer of suitable thickness is provided on a thin layer, and the woven structure is obtained by means of the method mentioned above. Woven structures with a sufficient number of strips and/or nodes can be manufactured in this manner so as to suit the purpose in a particularly simple manner as regards production technology.

The woven structure may alternatively be manufactured by means of selective growth. For this purpose, a mask can first be generated on the thin layer, whereupon a material is deposited only where no mask is present, for example in an electroplating or CVD process. Thus, for example, a metal oxide layer may serve as the mask on the thin layer, and subsequently a metal, for example silicon, may be deposited as a support structure outside the metal oxide layer.

These structures may obviously also be made by any other technique known in the art.

The object of the present invention is furthermore achieved by means of a device for retaining a substance originating from a radiation source by means of a filter which comprises a thin layer transparent to extreme ultraviolet and/or soft X-ray radiation, wherein said filter is resistant to high temperatures. The radiation naturally transmits a high power – i.e. energy per unit time – to the filter, so that the latter is quickly heated during operation. It is obviously possible to provide a device for the filter by means of which a given operational temperature can be adjusted.

The energy hits the filter within very short periods, in particular in the case of pulsed radiation sources, which means that an increase in the filter surface area can reduce the load on the filter material further, in particular with a surface area of more than 25 mm^2. To obtain an improved mechanical stability of the filter, the device may be constructed such that the thin layer is connected to a support structure in a high-temperature-resistant manner, or that the thin layer and the support structure are integrally manufactured.

This achieves a connection between the thin layer and the support structure which withstands the thermal loads coming from the radiation source for a long period.

Since the advantages of the further embodiments of the device correspond to those of the method according to the invention, a detailed description thereof will be dispensed with here.

Without limiting the general application of the method or the device for retaining a substance originating from a radiation source, a particularly advantageous application of the filter is found in a device for EUV lithography. The substance introduced by a radiation source is retained by the filter here, and a comparatively fast contamination of optical components is advantageously counteracted.

The application may be further developed with particular advantage in that the filter is operated at a temperature of approximately 900 °C to approximately 1300 °C. The filter can be positioned comparatively close to the radiation source because of the materials used for the thin layer and/or of a connection to the support structure that is resistant to high temperatures. These structural features remain intact during operation of the radiation source. In other words, the thin layer of the filter will neither evaporate nor melt under the temperature and pressure conditions prevailing in an industrial EUV exposure process.

The use of the filter may be improved in that the temperature for the filter is adjustable such that the retained substance evaporates under the prevailing pressure. A comparatively fast evaporation of the substance from the filter means that a sufficiently large residual surface remains available for the passage of the EUV rays.

A particularly advantageous embodiment of the use of the filter provides that the temperature for the filter is adjustable such that the retained substance evaporates from the filter at a higher rate than that at which it is deposited thereon. This achieves a comparatively fast removal of the substance deposited on the filter. Short-term fluctuations in the transmission of the filter owing to absorption of rays by substance particles deposited on the filter can even be substantially completely prevented thereby.

To render possible a quantitative reduction in the amount of substance retained by the filter, the use thereof may be advantageously further developed such that a foil trap is additionally arranged between the radiation source and the filter. The foil trap serves to reduce the quantity of substance originating from the radiation source in that it detracts kinetic energy from the substance particles. Various embodiments of the foil trap are the subject of earlier patent applications. The lower kinetic energy of the substance hitting the filter renders it possible to avoid sputtering, i.e. a removal of material, in particular from the thin layer.

The contamination of optical components of the lithography device and the wafer can be reduced by the use of the filter according to the invention in that the filter seals off the radiation source in the form of a window. Sealing-off by means of the filter creates a spatial separation between the radiation source and the optical components. The contamination of the optical components is almost completely suppressed thereby. The substance evaporating from the filter is also incapable of reaching the optical components.

Not only an increase in the energy coupled in and a suitable choice of the substance with a view to the conversion efficacy, but also an increase in the concentration of the substance in the radiation source serves to increase the power of the radiation source. The use of the filter for sealing off the radiation source renders it possible to design the operational method such that the substance reaches a partial pressure of approximately 10 Pa in the radiation source.

Further features and advantages of the invention will become apparent from the ensuing description of a number of embodiments and from the drawings to which reference is made and in which:

Fig. 1 is a diagrammatic cross-sectional view of a first embodiment of a filter arranged in the radiation path of a radiation source;

Fig. 1a is a side elevation, not true to scale, of a second embodiment;

Fig. 2 is a cross-sectional view of a semi-manufactured product in a third embodiment;

Fig. 2a is a perspective view of a fourth embodiment;

Fig. 2b is a vertical section of a fifth embodiment;

Fig. 3 is a diagrammatic side elevation of a first application; and

Fig. 4 is a further diagrammatic side elevation of a second application.

Equal reference symbols always refer to the same constructional features and always relate to Figs. 1 to 4, unless stated to the contrary.

In Fig. 1, a filter 10 is positioned for the purpose of retaining a substance 14 originating from a radiation source 12. The filter 10 comprises a thin layer 18 which is transparent to extreme ultraviolet and/or soft X-ray radiation 16. The entire filter 10 is constructed so as to be resistant to high temperatures so that it can be used in particular at high temperatures.

The filter 10 was manufactured such that the thin layer 18 is connected to a support structure 20 in a high-temperature-resistant manner. The thin layer 18 and the support structure 20 may be manufactured one after the other without any particular sequence having to be observed.

The thin layer 18 may be manufactured by means of a chemical and/or physical deposition process, for example a CVD or PVD process. The thin layer 18 comprises mainly substances that have certain optical characteristics. These substances have a high transparency for EUV rays 16, while at the same time, for example, they may substantially absorb rays with a wavelength in the UV, IR and VIS ranges, as well as undesired wavelengths in the EUV range. The thin layer 18 accordingly comprises preponderantly zirconium, niobium, molybdenum, silicon, zirconium carbide, zirconium dioxide, silicon carbide, silicon nitride, boron nitride, or a combination thereof.

It is also possible to manufacture a filter 10 as an integral whole, as is shown in Fig. 1a. The thin layer 18 and the support structure 20 have been manufactured from a single layer of material having a material thickness indicated with dotted lines. The thin layer 18 has a layer thickness 22 of approximately 100 nm both in this embodiment and in the embodiment of a filter according to the invention shown in Fig. 1.

The embodiment of the support structure 20 shown in Fig. 1a is inevitably manufactured from the same material as the thin layer 18, but obviously the support structure

20 shown in Fig. 1 may also comprise preponderantly zirconium, niobium, molybdenum, silicon, zirconium carbide, zirconium dioxide, silicon carbide, silicon nitride, boron nitride, or a combination thereof. The support structure 20 is generated in dependence on the application such that it reaches a thickness 24 in a range from approximately 1 μm to 1 mm.

The method of manufacturing a filter 10 will now be explained in more detail with reference to Fig. 2 and Fig. 2a. On a thin layer 18 with a layer thickness 22 obtained by means of conventional thin layer techniques on a suitable substrate, a second layer with a thickness 24 is deposited in a high-temperature-resistant manner. The thin layer 18 may comprise, for example, preponderantly silicon nitride, and the layer used for manufacturing the support structure 20 indicated with dots may comprise, for example, preponderantly silicon. Both the thin layer 18 and the support structure 20 are generally manufactured from a material having a melting point of at least 1300 °C.

Further substances besides the main components of the layers may be provided, preferably by means of PVD and/or CVD methods in the form of dopants and/or coatings. The support structure 20 may be given a strip structure, for example under formation of a grid or honeycomb-type woven structure 26, by means of erosion, laser processing, or photochemical etching in a further process step.

This results, for example, in the grid-type woven structure 26 shown in Fig. 2a obtained by irradiation with UV light through a suitable mask and a subsequent etching with hydrogen fluoride. Only the upper layer of silicon shown in Fig. 2 is attacked and removed thereby in a chemically selective manner in the vacuum furnace under formation of volatile compounds such as SiF_4 and hydrogen. The silicon nitride layer serving as the thin layer 18 is not affected by the treatment.

Fig. 2b is a vertical section of a filter 10 manufactured by the method described above. A support structure 20 in the form of a honeycomb-type woven structure 26 is integrally arranged on the thin layer 18. Such a geometrical arrangement of the support structure 20, which may obviously alternatively take the form of circles, triangles, and the like, renders it possible also to manufacture filters 10 of particularly large surface area, for example with a radius of 10 cm, which have satisfactory optical and especially mechanical properties.

One of the mechanical properties is, for example, a low thermal stress upon a temperature change between the support structure 20 and the thin layer 18. Such a large-area filter 10 withstands mechanical loads that occur during storage, transport, and use in a radiation source 12, for example pressure differences arising during evacuation. Obviously, a

bypass may also be provided between the radiation source 12 and a chamber containing the optical devices.

A first example of an application is shown in Fig. 3. A familiar foil trap 28 is arranged here between the filter 10 and the radiation source 12. Such an arrangement may be used in particular in EUV lithography. A substance 14 used in the radiation source 12 for generating the EUV radiation 16 reaches the filter 10. The filter 10 has a thin layer 18 and a support structure 20. At least the thin layer 18 is transparent to the EUV radiation 16. The filter 10 is heated by an absorption of radiation 16 at a surface of the filter 10 facing the radiation source. The filter is operated in a temperature interval from approximately 900 °C to 1300 °C. The temperature is adjusted during this, for example, such that the substance 14 retained by the filter 10 can evaporate under the prevailing pressure. A high transmission coefficient of the filter 10 can be ensured thereby in particular during operation of the radiation source 12. The foil trap 28 is capable, for example, of reducing the kinetic energy of the substance 14 migrating towards the filter 10 to such an extent that a sputtering of the thin layer 18 is substantially entirely suppressed.

Fig. 4 shows a second example of an application. The side elevation, not true to scale, shows a filter 10 whose temperature is adjustable by means of an additional device (not shown) such that the substance 14 used by the radiation source 12 is retained, while the substance 14 deposited on the filter 10 evaporates at a higher rate from the filter 10. A deposition of substance 14 on the filter 10, which is transparent to the rays 16, can be substantially fully suppressed, averaged over time, in this manner. As is apparent from Figs. 3 and 4, the filter 10 may be constructed in the manner of a window which seals off the radiation source 12 in the propagation direction of the rays 16. Said window may be arranged as a rectangle or substantially circular thanks to the support structure 20, which is either connected to the thin layer 18 in a manner resistant to high temperatures or is integral therewith. It is in particular the support structure 20 that renders it possible to realize an enlarged filter surface area, the filter 10 itself withstanding the mechanical loads during operation at a temperature in a range from approximately 900 °C to 1300 °C.

The mechanical stability of the filter 10 renders possible a spatial separation of the radiation source 12 and the substance 14 used for generating the radiation 16 from an optical system (not shown) of an EUV lithography device. The substance 14 in the radiation source 12 can be used as a working gas, for example in the form of a tin vapor, in particular through the supply of thermal energy, and can reach a partial pressure of approximately 10 Pa. The power of a high-power radiation source 12 can be increased thereby.

Obviously, a substantially transparent gas such as, for example, helium may be introduced into the chamber 30 for achieving a pressure equalization between the radiation source 12 and a chamber 30 arranged behind the filter 10 in the propagation direction of the radiation 16.

The invention provides a method of manufacturing a filter and a device for retaining a substance originating from a radiation source, which device renders possible the use of in particular high-power radiation sources, safeguards a permanent transmission of the EUV radiation during operation, and in addition can be given a construction with a large surface area. The filter according to the invention, moreover, may be used for avoiding a contamination of optical components of an EUV lithography device.

LIST OF REFERENCE NUMERALS

10	filter
12	radiation source
14	substance
16	radiation
18	thin layer
20	support structure
22	layer thickness
24	thickness
26	woven structure
28	foil trap
30	chamber